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THE REGIONAL STRUCTURE OF PRODUCTION AND INPUT DEMAND IN BRAZILIAN AGRICULTURE, 1970-1986

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Abstract

This paper explores the regional structure of production and input demand in Brazilian agriculture for the 1970-1986 period. The paper shows that the increasing participation of agricultural exports in total agricultural GDP by region during that period has been due not only to favorable relative price for agricultural exports, but also to technological changes in favor of agricultural export crops.

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1 Introduction

This paper analyzes how the output mix in Brazilian agriculture has been shaped by changing prices and technologies in the past. It is shown, using a divisia index composed of beans, maize, cassava, rice, and wheat, that the share of domestic food-crop products in total agricultural products has declined substantially.[1] On the other hand, it is shown that agricultural-export products (using the quantity divisia index of coffee, cotton, sugar, and soybeans), have increased their share of total agricultural products. Agricultural-export products, as shown in Table 1, are now as important as food crops in the North-East, South, and Center-West of Brazil. In the South-East these products increased their relative importance from 56.8% in 1970-1980 period to 67.6% in 1981-86.

One explanation for the rapid restructuring of this output mix in Brazilian agriculture is the favorable relative price for agricultural exports. The relative price of agricultural exports to domestic food crops increased in all regions of the country (see Table 2). This favorable tendency for agricultural-export prices may be explained by the increasing demand for these products in world markets and a partial opening of the economy. However, this demand-oriented explanation of the changing output-mix in Brazilian agriculture is

[1] The divisia index is a weighted sum of growth rates, where the weights are each components' share in the total value of output (Hulten, 1973).

incomplete. For example, from our data it can be seen that the share of agricultural-exports in the Center-West increased substantially from 19.7% in 1970-1980 period to 47.8% in 1981-1986, but agricultural-export prices relative to domestic food crop prices only increased from 1.13 in 1970-1980 to 1.16 in the 1981-1986 period. Thus the change in output mix is also in part explained by the bias in technological change in favor of agricultural export crops.

The 1970-1980 period saw a rapid decline in the share of rural labor compensation in total agricultural production costs in the South-East, South, and Center-West regions. This declining share of labor costs was accompained by a rapid mechanization of agricultural production and a comparable rise in the share of machinery costs (see Table 3). The share of land services (rental costs for land) in total agricultural production costs, in turn, increased in the South-East and in the Center-West. Factor prices do not appear to be the main cause for the changing factor mix. The main cause is the change in output mix. As can be seen in Table 4, all factor prices increased in almost the same proportion in 1981-1986 period compared to the 1970-1980 period. Thus, there was a bias in technological change towards agricultural exports. This, in turn, changed Brazil's agricultural output mix which then influenced the change in factor mix seen in Table 3.

To study these phenomena, the framework of a multi-product multi-input translog cost function is utilized. The translog joint cost function is estimated for the period 1970-1986 using appropriate regional and national data. Neoclassical duality theory provides an approach for empirically investigating the production structure of Brazilian agriculture on a regional basis.

Table 1: Percentage Shares in Total Value of Production of Food Crops and Agricultural Export Crops Measured by a Quantity Based Divisia Index*, by Region, by Periods, 1970-86.

Region	1970 - 1980 Food Crops (1)	Ag-Exports (2)	Total (3)	1981 - 1986 Food Crops (4)	AG-Exports (5)	Total (6)
North	94.1	5.9	100	85.6	14.4	100
North-East	66.6	33.4	100	52.1	47.9	100
South-East	43.2	56.8	100	32.4	67.6	100
South	57.4	42.6	100	55.2	44.8	100
Center-West	80.3	19.7	100	52.2	47.8	100

Notes: (1) Food Crops consist of beans, maize, casava, rice and wheat.
(2) Export Crops consist of coffee, cacao, sugar and soybeans.

Table 2: Divisia Price Indices and Relative Price Index of Food Crops and Agricultural Export Crops, by Region, by Period, 1970-1986.
(Basis year 1980 = 1.00)

	Food Crops		AG - Exports		Ag-Exp/Food Crops	
	1970-80	1981-86	1970-80	1981-86	1970-80	1981-86
Region	(1)	(2)	(3)	(4)	(5)	(6)
North	0.25	67.8	0.31	94.5	1.24	1.39
North-East	0.23	34.4	0.22	49.9	0.95	1.45
South-East	0.22	49.6	0.26	80.6	1.18	1.63
South	0.23	53.7	0.27	70.6	1.17	1.31
Center-West	0.23	56.6	0.26	65.4	1.13	1.16

Table 3: Percentage Shares in Total Agricultural Production Costs of Labor, Land, and Capital Services, by Region, by Period, 1970-1986.

	Period 1970 - 1980				1981 - 1986			
Region	Labor	Land	Machinery	Total	Labor	Land	Machinery	Total
North	74.6	20.7	4.7	100	73.3	19.9	6.8	100
North-East	74.5	22.0	3.5	100	73.8	20.4	5.8	100
South-East	69.9	11.8	18.3	100	54.5	15.9	29.6	100
South	53.4	21.3	25.3	100	41.1	19.8	39.1	100
Center-West	65.2	20.0	14.8	100	43.5	25.8	30.7	100

Table 4: Average Rural Wages, Land Rent and Tractor Prices in Current Cruzados, by Region for Selected Periods 1970-1986.

	Rural Wages			Land Rent			Price of Machinery		
	1970-80	1981-86	Δ%	1970-80	1981-86	Δ%	1970-80	1981-86	Δ%
North	4.12	45.3	1099.5	-	-	-	-	-	-
North-East	2.98	32.7	1097.3	-	-	-	-	-	-
South-East	4.07	44.8	1100.7	-	-	-	-	-	-
South	4.27	47.0	1100.7	-	-	-	-	-	-
Center-West	3.95	43.5	1101.3	-	-	-	-	-	-
Brazil	-	-	-	2.78	30.6	1100.7	453	4,986	1100%

The main objective of this study is to empirically analyze Brazilian agriculture for two periods (1970-80 and 1981-86). To do this we estimate the pairwise elasticities of substitution between inputs for each period as well as the price elasticies of demand for inputs. This study also attempts to test the hypothesis that the changing output mix in Brazilian agriculture by region has been due not only to changing relative product prices but also due to technological change biased in favor of agricultural export products.

2 Specification of the Model

Let the technology of Brazilian agriculture be represented by the following multi-product multi-input indirect cost function:

$$C^{*} = f(Q_{FC}, Q_{EX}, P_{L}, P_{M}, P_{K}, t), \tag{1}$$

where C^{*} is the minimized total cost; Q_{FC} and Q_{EX} are food crops and agricultural export crops, respectively; P_L, P_M, and P_K are the prices of labor, machinery, and land services, respectively; and t is time, an index of technological change.

For econometric estimation, the following multi-output multi-input Hicks-non-neutral form is employed for (1):

(2)

where i,k = Food-crops, Ag-Export crops; and j,l = Labor, Machinery, Land. Greek letters are parameters; ln stands for natural logarithms; and $\gamma_{ik} = \gamma_{ki}$ and $\delta_{jl} = \delta_{lj}$; . The interactions between output and the variable for time (t) allow the effects of technical change to vary with the scale of production, and interactions with factor prices measure the input-specific effects of technological change.

From the cost function (2) and Shephard's lemma, the conditional factor demands, $x_j = \partial C/\partial P_j$, are derived. The cost share equations are derived as follows:

$$S_j = \beta_j + \sum_{l=1}^{3} \delta_{jl} lnP_1 + \sum_{k=1}^{2} \rho_{kj} lnQ_k + \nu_{jt} \ln t, \tag{3}$$

where j,l = Labor, Machinery, Land; k = Food-crops, Ag-Exports; and $S_j = P_j x_j/C = \partial \ln C/\partial P_j$.

Following Uzawa [1962], a measure of the Allen partial elasticities of substitution between inputs i and j can be derived from the indirect cost function (1) as:

$$\sigma_{lj} = \frac{\left[\left(\dfrac{\partial^2 C}{\partial P_l \partial P_j}\right) \cdot C\right]}{\dfrac{\partial C}{\partial P_l} \dfrac{\partial C}{\partial P_j}} \tag{4}$$

In the translog model (2), we obtain:

$$\sigma_{lj} = \frac{\delta_{jl} + S_l S_j}{S_l S_j}, \quad if\ l \neq j \tag{5}$$

and

$$\sigma_{jj} = \frac{[\delta_{jj} + S_j(S_j - 1)]}{S_j^2}, \quad if\ j{=}l. \tag{6}$$

Following Binswanger [1974], the (own- and cross-) price elasticities of demand for individual inputs may be obtained from (3) and (5) as:

$$\epsilon_{jl} = S_{jl} \cdot \sigma_{jl} \tag{7}$$

Notice that the own- and cross-price elasticities of factor demand are not symmetrical as are the substitution elasticities.

The changing output mix caused by technological change in output space is measured by detecting movements of the expansion path in output space (Kuroda, 1988). The technological change in output space may be defined as:

$$B_{ik} = \frac{\partial \ln \left(\dfrac{\frac{\partial C}{\partial Q_i}}{\frac{\partial C}{\partial Q_k}} \right)}{\partial t} = \frac{\partial \ln MC_i}{\partial t} - \frac{\partial \ln MC_k}{\partial t} \tag{8}$$

where i,k = Food-crops, Agricultural-exports; and MC_i stands for marginal cost of output i. Technological change in output space is biased toward output k (or against output i) if $B_{ik} > 0$, neutral if $B_{ik} = 0$, or biased toward output i (or against k) if $B_{ik} < 0$. Following Kuroda, the measure of technological biase is output space may be derived from the translog cost equation as follows:

$$\beta_{ik} = \frac{(\mu_{ie} + G(AC_i))}{\epsilon_j \cdot t} - \frac{(\mu_{kt} + G(AC_k))}{\epsilon_k \cdot t}, \tag{9}$$

where i,k = Food-crops, agricultural-exports; ϵ_i is the cost-output elasticity (or logarithmic marginal cost) of output i; and G(AC_i) is the rate of growth of the average cost (AC) of output i. The cost-output elasticity of output i, ϵ_i, may be obtained from the translog function as:

$$\epsilon_i = \frac{\partial \ln C}{\partial Q_i} = \alpha_i + \sum_{j=1}^{3} \rho_{ij} lnP_j + \sum_{k=1}^{2} \gamma_{ik} lnQ_k + \mu_{it} \ln t, \tag{10}$$

where i,k = Food-crops, Agricultural-Exports; and j = Labor, Machinery, Land.

3 Data Description

In this model two outputs (Food-crops, Agricultural-Export crops) have been defined. Both are measured by quantity divisia indices. The food crop products for this exercise include: beans, maize, cassava, rice, and wheat. Agricultural export crops include: coffee, cotton, sugar, and soybeans. Three inputs are considered: rural labor, only consisting of remunerated workers; agricultural machinery as a proxy for farm capital; and land services (the rental cost of land). Fertilizer, pesticides, feed, seeds, etc., could not be included because an appropriate time series for the whole period and by region was not available for these inputs.

4 Statistical Methods

In the neoclassical duality model employed here, input prices are used rather than physical quantities. These consist of wages for permanent workers; the price of four wheel tractors as a price proxy for farm machinery; and the rent of land as a price for land services. Total agricultural cost is defined as the sum of total expenditure on agricultural labor (i.e., number of workers times the annual wage for permanent workers), total expenditure on cultivated land (both temporary and permanent), and total expenditure for machinery services (20% depreciation of the total value of the annual stock of tractors).

The cost shares of factors (labor, machinery, and land) were obtained by dividing the total expenditure on each factor by total cost. The data is taken from various Brazilian government publications. The results are available for each year. However for convenience of exposition, two periods are chosen for analysis 1970-80 and 1981-86. The findings have been summarized for each of these historically distinct periods, in which the first period (1970-80) represents a high growth period for agriculture and the economy as a whole and one in which marked technological change was occurring in Brazilian agriculture. The second period (1981-86) represents a slower growth period in which the pace of technological change was reduced with a decline in the demand for capital inputs in agriculture.

The translog cost function (2) must satisfy linear homogeneity in factor price conditions. This requires that

$$\sum_{j=1}^{3} \beta_j = 1, \quad \sum_{k=1}^{2} \delta_{ik} = 0, \quad \sum_{j=1}^{3} \rho_{ij} = 0, \quad \sum_{j=1}^{3} \nu_{jt} = 0 \tag{11}$$

where i,k = Food-Crops, Ag-Exports; and j = Labor, Machinery, Land.

Because the cost shares must add to 1, one of the share equations from (3) is redundant. Using the price of machinery as a numeraire and imposing the above parameter restrictions, the system represented in equation (3) is estimated through the labor share and land share equations. The equations of the system are seemingly unrelated in the sense of Zellner [1962], therefore, the joint generalized least square procedure is used. The implied estimates of the model (i.e., the machinery share equation estimates) are obtained by using the parameter relationships of the linear homogeneity restrictions.

The estimation procedure also considers the possibility of first-order autocorrelation in the translog cost function and in the share equations. For simplicity, it is only considered for the case where the matrix of first-order autocorrelation coefficients is diagonal in the share equations. This implies that all the autocorrelation coefficients of the share equations are identical. The autocorrelation coefficients are denoted Θ_v for the translog cost function and Θ_u for the share equations. Each equation is written as a function of current and one-period lagged exogenous variables as well as for the corresponding one-period lagged cost or factor shares (Berndt and Savin, 1975). The system, however, becomes non-linear in the parameters. Thus, all estimations were made by computing the full information maximum likelihood (FIML) algorithm of Berndt, Hall, Hall, and Hausman [1974], which allows the system to be non-linear in the parameters. If the system is linear this algorithm then becomes equivalent to Zellner's method for seemingly unrelated regression equations.

Since the output variables (i.e., food-crops, and agricultural export crops) may be endogenously determined, input decisions should depend not on actual, realized output but on expected or planned output. For this reason, following Antle and Crissman [1988], a translog specification of both supply functions is used to obtain the fitted values of $\ln Q_i$ (i = Food-crops, Ag-Export crops). The fitted values are used as estimates of the expected cost function estimation, leading to estimates of the cost function free of simultaneous equation bias.

5 Empirical Results

The translog cost function (2) and the labor and land share equations in (3) were estimated by FIML procedures to check the goodness of fit. The adjusted R^2s were 0.998, 0.973, 0.779 for the translog cost function, labor and land share equations, respectively, indicating a fairly good fit for our translog cost function.

An important objective of this effort was to measure the elasticities of substitution between pairs of inputs during the 1970-86 period covered by the data. These results highlight the process of technological change during this period. The Allen partial elasticities of substitution were computed using equations (5) and (6) for the periods 1970-1980 and 1981-1986 as well as for the five different regions considered in the study; i.e., North, North-East, South-East, South, and Center-West. The own- and cross-price elasticities of factor demand, in turn, were computed using equation (7). The estimated substitution matrices are not reported here, because the own- and cross-price factor elasticities reported in tables 5 and 6 provide essentially the same information on the substitution possibilities inherent in Brazilian agricultural technology.

In interpreting the findings in tables 5 and 6, it should be remembered that the factor prices are exogenous while the quantity of labor, land and machinery services are endogenous. Thus, the coefficient for own-price factor demand elasticity indicates, the effect of an exogenous increase in a factor price on its own demand. The coefficients for cross-price factor demand elasticities, however, indicate the percentage effect of an exogenous increase in the price of one factor on the demand for the other factor.

Table 5 shows that the own-price elasticity of labor demand is relatively stable through both periods and among regions. The own-price elasticities in columns 1 and 2 fluctuate between -0.067, for the North-East in the first period, and -0.246 for the South in the second period. The low own-price elasticities of demand for labor, indicate that high decreases in rural wages are necessary to increase the demand for labor in agriculture.

The own-price of land demand elasticities are also very low, indicating a low response of the demand for land to the changing rental cost of land. Curiously, the South-East shows the wrong sign. Despite increases in the rental cost of land, the demand for land still increased in this region. The high incidence of agricultural credit subsidies in this region very likely explains this result.

Table 5 Own-Price Elasticities of Demand for Inputs, by Period, by Region, 1970-86

Region	Labor		Land		Machinery	
	1970-80	1981-86	1970-80	1981-86	1970-80	1981-86
	(1)	(2)	(3)	(4)	(5)	(6)
North	-0.072	-0.075	-0.054	-0.008	-0.871	-0.875
North-East	-0.067	-0.071	-0.067	-0.023	-0.854	-0.868
South-East	-0.105	-0.196	0.425	0.151	-0.791	-0.691
South	-0.205	-0.246	-0.051	-0.005	-0.728	-0.599
Center-West	-0.143	-0.241	-0.041	-0.131	-0.820	-0.670

Table 6 Own and Cross-Price Elasticities of Demand for Inputs, by Region for the Period 1970-1986 (Mean Values).

Region	Price of:	Demand for Labor	Demand for Land	Demand for Machinery
North	Labor	-0.072	0.010	0.064
	Land	0.034	-0.039	0.006
	Machinery	0.852	0.023	-0.875
North-East	Labor	-0.069	0.016	0.053
	Land	0.055	-0.051	-0.004
	Machinery	0.886	-0.018	-0.868
South-East	Labor	-0.142	-0.096	0.239
	Land	-0.448	0.296	0.153
	Machinery	0.664	0.091	-0.754
South	Labor	-0.224	-0.096	0.320
	Land	-0.222	-0.036	0.258
	Machinery	0.505	0.176	-0.680
Center-West	Labor	-0.188	-0.022	0.223
	Land	-0.087	-0.080	0.167
	Machinery	0.590	0.180	-0.770

On the other hand, the own-price elasticities of demand for machinery are very high in all regions (columns 5 and 6 of Table 5). This indicates that a 10% decrease in price of machinery will increase the demand for machinery close to or more than 8% in most regions. The lowest own-price machinery demand elasticity is found in the South during the second period (-0.599). It is interesting to note that the elasticities are markedly lower in the second period for the high growth agricultural areas of the South, Center-West and the South-East, reflecting the decline in the impetus of capital driven technological change during this recession influenced period.

The cross-price elasticities of demand for inputs in Table 6 indicates that labor and machinery are important substitutes in all regions (i.e., they have positive coefficients). Thus, in the North the average elasticity of substitution between capital and labor is 0.852, indicating that an increase of 10% in the price of machinery will increase the demand for labor 8.52%. The lowest level of substitutability between labor and machinery was found in the South.

Land and labor appear to be weak substitutes in the North and North-East, but are complements in the South-East, South, and Center-West (i.e., they have negative signs). The only instance of a high degree of complementarity was found in the South-East (-0.448). Machinery and land also appear to be substitutes in all regions except the North-East (where the elasticity is relatively weak and insignificant).

The cross-price elasticity coefficients between land and machinery fluctuate between -0.018 in the North-East and 0.180 in the Center-West. These results in Table 6 indicate that a 10% decrease in the price of machinery would increase the demand for land 0.18% in the

North-East, but would decrease the demand for land 1.8% in the Center-West. The relatively higher positive machinery-land cross elasticities in the Center-West, South and South-East make sense in that these were regions of high capital intensive, land expansion activities where a price decline in the proxy for capital (i.e., machinery) would decrease the demand for land in that machinery would be substituting for land.

Table 7 indicates that the inititally high machinery - labor substitutability has declined through time in all the regions but particularly in the Center-West, South and South-East, reflecting the decline in the impetus of capital intensive technological change in the low growth 1980's. The land-machinery substitutability, on the contrary, has increased in the second period as compared with the first period in all regions. The labor-land complementarity found in the South-East, South, and Center-West in Table 7 has increased from -0.09, -0.06, and -0.02 in the first period to -0.112, -0.161, and -0.08 in the second period respectively reflecting the mutual decline in the price of labor (real wages) and the demand for land in this low growth period.

To examine the rapid growth of agricultural-export crops on the supply side during the period 1970-1986, a bias of technological change towards agricultural-export crops output was hypothesized, that is that $B_{fc\ ex} > 0$. To test this hypothesis, $B_{fc\ ex}$ and the annual growth-rate of the marginal costs of producing food crops and agricultural-export crops were computed using equations (9) and (10) for the 1970-86 period for each region. These estimates are provided in Table 8.

Table 7 Own and Cross-Price Elasticities of Demand for Inputs, By Region, by Period, 1970-1986.

Region	Price of:	Demand for: Labor 1970-80	Labor 1981-86	Land 1970-80	Land 1981-86	Machinery 1970-80	Machinery 1981-86
North	Labor	-0.072	-0.075	0.016	-0.002	0.056	0.077
	Land	0.054	-0.008	-0.054	-0.008	-0.000	0.016
	Machinery	0.873	0.827	-0.003	0.048	-0.871	-0.875
North-East	Labor	-0.67	-0.71	0.023	0.004	0.044	0.067
	Land	0.079	0.015	-0.067	-0.023	-0.011	0.008
	Machinery	0.926	0.886	-0.071	0.027	-0.854	-0.875
South-East	Labor	-0.105	-0.196	-0.092	-0.112	0.197	0.308
	Land	-0.528	-0.383	0.425	0.151	0.103	0.231
	Machinery	0.725	0.567	0.066	0.124	-0.791	-0.875
South	Labor	-0.205	-0.246	-0.064	-0.161	0.269	0.407
	Land	-0.158	-0.334	-0.051	-0.005	0.209	0.339
	Machinery	0.553	0.427	0.175	0.172	-0.729	-0.599
Center-West	Labor	-0.143	-0.241	-0.022	-0.081	0.165	0.322
	Land	-0.065	-0.137	-0.041	-0.131	0.106	0.267
	Machinery	0.675	0.456	0.145	0.225	-0.820	-0.680

Table 8 The Bias in Technological Change Measured by the net Difference in the Rate of Growth of the Marginal Cost of Producing Domestic Foodcrops and Export Crops(G_{FC}-G_{EX}) by Region for Selected Periods 1970-86. Net Difference (G_{FC}-G_{EX}) per Year for the Period.
(% per year)

Region	1970-80	1981-86
North	1.4	5.6
North-East	2.4	3.6
South-East	8.4	11.7
South	7.1	-3.6
Center-West	10.4	19.5

Table 8 shows that technological change during the 1970-1980 period was biased toward agricultural export production in all regions. This indicates that the average annual marginal cost of producing domestic food crops grew more rapidly than the marginal cost of producing agricultural export crops. The highest bias of technological change toward export crops was found in the Center-West where the marginal cost of producing domestic food crops grew 10% per year more than the marginal cost of producing export crop output. The lowest bias of technological change toward export crops was only 1.4 percent per year. In the second period, the bias toward export crops increased in all regions, except the South. In the South during the second period the bias of technological change was in favor of domestic food crops instead. During this period the marginal cost of producing export crops in the South-East grew 3.6% faster than that of producing food crops. This is consistent with our earlier finding that by the mid 1980s yield breakthroughs had occurred for many domestic food crops, largely in the South. These yield increases would logically be associated with declining marginal costs of production.

6 Concluding Remarks

This section analysed the structure of agricultural production in Brazil using the translog approximation to the cost function. A neoclassical duality specification was used for this purpose. Food-crops and agricultural-export crops were treated as two distinct outputs instead of being lumped together into an aggregate product. Of particular importance was estimation of the elasticities of substitution between inputs and the price elasticities of factor demand. Machinery was found to be highly substitutable for labor in all regions, and a substitute for land in all the regions but the North-East. The results also show a declining substitutability between machinery and labor along with an increasing substitutability between machinery and land in the more recent period. This information is useful for policy. If this trend is to continue we may expect a slowing down in the mechanization and intensified expansion of cultivated land. The increasing labor-land complementarity found in the South-East, South, and Center-West regions indicates, in turn, that land expansion should be complemented with an increasing demand for rural workers.

Another finding of the empirical analysis indicates that technological change was biased in favor of producing export crops in all the regions of the country during the first period. This technological bias increased in the second period in all the regions but the South where for the first time, the marginal cost of producing domestic food crops was less than for export crops.

A limitation of this analysis is the inability to include livestock products and intermediate products like pesticides, fertilizer, seeds, etc. in our multi-product, multi-input cost function. This is due to the fact that no time series data was available on the value of livestock products, and, at the same time, no times series data exist for total expenditures on intermediate inputs (fertilizers, pesticides, etc...) at a regional level. At the same time one should note the lack of a complete annual series at a regional level for the number of rural workers, machinery units, and cultivated land. Nevertheless, data from four census benchmark years was available, thus, it was necessary to interpolate to complete the data for the remaining years in the 1970-86 period for these variables. Our estimates therefore should be regarded as broad indicators of technological change and input demand elasiticities at the regional level in Brazil. In any event the results are both analytically and empirically consistent with what we know about the process of technological change in Brazil. Their value lies in documenting the paths of technological change in a more rigorous, and detailed, fashion than has been available before on a regional level. Future studies should be in a position to build on the methods of analysis explored here to better document the future growth of Brazilian agriculture.

REFERENCES

Antle, J.M., and Charles C. Crissman, (1988), "The Market for Innovations and Short-Run Technological Change: Evidence from Egypt," Economic Development and Cultural Change, 36.

Berndt, E. R. and N.E. Savin (1975), "Estimation and Hypothesis Testing in Singular Equation Systmes with Autoregressive Disturbance," Econometrica, 43.

Berndt, E.R., B.H. Hall, R.E. Hall, and J.A. Hausman (1974), "Estimation and Infrecne in Nonlinear Structural Models," Annals of Economic and Social Measurement, October.

Hulten, C. R. (1973), "Divisia Index Numbers," Econometrica, 41.

Kuroda, Y. (1988), "The Output Bias of Technological Change in Postwar Japanese Agriculture," American Journal of Agricultural Economics, 70.

Uzawa, H. (1964), "Duality Principles in the Theory of Cost and Production," International Economic Review, 31.

Zellner, A. (1962), "An Efficient Method of Estimating Semingly Unrelated Regressions and Tests for Agregation Bias," Journal of the American Statistical Association, 57.